REMARKS

The foregoing amendment is to place the allowable subject matter of dependent claims in independent form for allowance, rather than to avoid prior art.

Applicant respectfully requests reconsideration of the above identified application. Claims 1-15, 20-24 and 29-38 are pending. Claims 3-4, 11-13, 21-23 and 30-31 are amended. Claims 1-2, 10, 20 and 29 are cancelled.

The remaining comments are directed to the Office Action mailed on September 23, 2004.

The Office Action indicates that allowable subject matter is presented in claims 3-9, 11-15, 21-24 and 30-38. Therefore Applicant has amended claims 3, 11, 21 and 30 to put them in independent form.

Applicant respectfully disagrees with the reasons for rejection of claims 1-2, 10, 20 and 29 as presented in the Office Action, but being respectful of the Examiner's time will not refute the rejections in the present communication, but has instead canceled claims 1-2, 10, 20 and 29 to pursue them further in a continuation of the present application.

35 USC § 112, First Paragraph Rejection

The Office Action indicates Claims 20-24 stand rejected under 35 USC § 112, first paragraph, for allegedly failing to meet the enablement requirement and Claims 20 and 22 stand rejected for reciting only a single means limitation citing MPEP § 2164.08(a).

With regard to the enablement requirement, Applicant respectfully submits the claims meet the enablement requirement. With regard to Claims 20-24, Applicant respectfully submits that one is enabled by the present specification to make and use the entire scope of the claimed invention without undue experimentation.

The determination of the appropriateness of a rejection based upon the scope of a claim relative to the scope of the enablement involves two stages of inquiry. The first is to determine how broad the claim is with respect to the disclosure. The entire claim must be considered. The second inquiry is to determine if one of ordinary skill in the art is enabled to make and use the entire scope of the claimed invention without undue experimentation (MPEP § 2164.08).

The limitations of the canceled claim 20 have been included in claim 21 as amended and sets forth, "a verification system comprising means for strengthening a first antecedent label for an edge in an assertion graph." Applicant disclosed in the present specification (e.g. page 19 line 3 through page 20 line 12, [emphasis added]) that:

> For one embodiment, an antecedent strengthening sequence can be defined for model checking according to the normal satisfiability criteria defined above. For an assertion graph G and a model M=(Pre, Post), <u>define an antecedent strengthening sequence</u>, Ant_n: E→P(S), mapping edges between vertices in G into state subsets in M as follows:
>
> $Ant_1(e) = Ant(e)$, and
>
> $Ant_n(e) =$ Intersect ($Ant_{n-1}(e)$, ($\text{Union}_{\text{for all e' such that Head(e')=Tail(e)}}$ $Pre(Ant_{n-1}(e'))$)), for all n>1.
>
> In the antecedent strengthening sequence defined above, <u>a state s is in the nth antecedent set of an edge e if it is a state in the n-1th antecedent set of e, and one of the states in a pre-image set of the n-1th antecedent set of an outgoing edge e'</u>. Again, it will be appreciated that the Union operation and the Intersect operation may also be interpreted as the Join operation and the Meet operation respectively.
>
> For one embodiment, <u>Figure 3b illustrates a method for computing the strengthened antecedents for an assertion graph</u>. Box 321 represents marking all edges in the assertion graph active. Box 322 represents testing the assertion graph to identify any active edges. If no active edges are identified, then the method is complete. Otherwise, an active edge, e, is selected and marked not active as represented by box 323. <u>Box 324</u> represents <u>recomputing the antecedent label for edge, e, by keeping in the antecedent label for edge e, any states that are already contained by the antecedent label for edge e and also contained by some pre-image set for the antecedent label of any edge, e', outgoing from e</u>. Box 325 represents testing the antecedent label for edge e to determine if it was changed by the recomputation. If it has changed, all incoming edges to e are marked as active, as represented by Box 326. In any case, the method flow returns to the test for active edges represented by Box 322.
>
> For example, <u>Figure 5a shows iterations of antecedent strengthening of graph 202</u> on model 101. The antecedent sets are shown for edges 517 as S and 518 as

> {s1}. Therefore the <u>antecedent set for edge 527 is computed as the antecedent set for edge 517, S, intersected with the pre-image set of the antecedent set of outgoing edge 518, denoted Pre({s1}), which is {s0}</u>. Thus the antecedent set of edge 527 is strengthened to {s0} and the antecedent sets for edges 528 and 529 are unchanged. In the final iteration, no antecedent sets are changed and so a fixpoint solution 502 is reached and the iterations are terminated.

Applicant respectfully submits that one of ordinary skill in the art is enabled to make and use means for strengthening an antecedent label for an edge in an assertion graph for model checking without undue experimentation.

Claim 21 as amended further sets forth, "means for joining any pre-images for antecedent labels of outgoing edges from the edge in the assertion graph; and means for keeping, in the strengthened antecedent label for the edge, states already contained by the first antecedent label for the edge and also contained by the joined pre-images for antecedent labels of outgoing edges from the edge,"--for example as disclosed above with regard to the antecedent strengthening sequence defined above, with regard to Box 324 of Figure 3b, and with regard to edge 527 of Figure 5a.

Claim 22 as amended further sets forth that, "the first antecedent label is one of a plurality of antecedent labels including a second antecedent label encoded along with the first antecedent label into a third antecedent label by a symbolic indexing function."

Applicant disclosed in the present specification (e.g. page 33 line 4 through page 34 line 9, [emphasis added]) that:

> Therefore the final simulation relation indicates that <u>symbolic extension of model 1001 strongly satisfies assertion graph 1103 on the symbolic lattice domain ($\{B^m \rightarrow P\}, \subseteq_S$)</u>. <u>Intuitively this means that the model 1001 strongly satisfies both assertion graphs 1101 and 1102</u> on the lattice domain ($P, \subseteq$).
>
> Accordingly, by applying previously disclosed methods, for example, of Figure 6a or of Figure 8b, symbolic model checking can be performed using the normal satisfiability criteria if <u>a strengthened antecedent sequence can be computed symbolically</u>.
>
> For one embodiment, <u>an antecedent strengthening sequence</u> $Ant_S(\underline{v}^-, \underline{v})$ can be <u>defined</u> for model checking according to the normal satisfiability criteria as follows:
>
> $Ant_{S1}(\underline{v}^-, \underline{v}) = Ant_S(\underline{v}^-, \underline{v})$, and
> $Ant_{Sn}(\underline{v}^-, \underline{v}) = Meet_S\ (Ant_{Sn-1}(\underline{v}^-, \underline{v}), (Join_{S\ \text{for all } \underline{b} \text{ in } Bm}\ Pre_S(Sim_{Sn-1}(\underline{v}, \underline{v}'))[b/\underline{v}']\ ))$, for all $n>1$.

For one embodiment, Figure 12b illustrates a method for computing the strengthened antecedents for an assertion graph on a symbolic lattice domain. In box 1221 all edges in the assertion graph have their original antecedent label values. Box 1224 represents recomputing the symbolic antecedent label for edges ($\underline{v}^-$, $\underline{v}$), by keeping in the antecedent label for edges ($\underline{v}^-$, $\underline{v}$), any states that are already contained by the symbolic antecedent label for edges ($\underline{v}^-$, $\underline{v}$) and also contained by some pre-image set for the antecedent label of edges ($\underline{v}$, $\underline{v}'$), outgoing from ($\underline{v}^-$, $\underline{v}$) and formed by substituting any $\underline{b}$ in B^m for $\underline{v}'$. Box 1225 represents testing the symbolic antecedent labeling for edges ($\underline{v}^-$, $\underline{v}$) to determine if it was changed by the recomputation. If it has changed, the method flow returns to the recomputation represented by Box 1224. Otherwise a fixpoint has been reached and the method terminates at Box 1225.

Accordingly, antecedent strengthening may be applied to symbolic model checking to provide normal satisfiability and therefore satisfiability of justification properties on the symbolic lattice domain ($([B^m \rightarrow P], \subseteq_S)$). It will be appreciated that the methods disclosed herein may be applied orthogonally in combination, thereby producing an exponential number of embodiments according to the combination of disclosed methods.

Applicant respectfully submits that one of ordinary skill in the art is enabled to make and use means for strengthening an antecedent label for an edge in an assertion graph for symbolic model checking without undue experimentation.

Applicant also submits that joining any pre-images for antecedent labels of outgoing edges from the edge in the assertion graph; and keeping, in the strengthened antecedent label for the edge, states already contained by the first antecedent label for the edge and also contained by the joined pre-images for antecedent labels of outgoing edges from the edge, as set forth in claim 21, is enabled for symbolic model checking without undue experimentation--for example as disclosed above with regard to the antecedent strengthening sequence $Ant_S(\underline{v}^-, \underline{v})$, and with regard to Box 1224 of Figure 12b.

Applicant also submits that a first antecedent label being one of a plurality of antecedent labels including a second antecedent label encoded along with the first antecedent label into a third antecedent label by a symbolic indexing function, as set forth in claim 22, is enabled for symbolic model checking without undue experimentation--for example as disclosed above with regard to assertion graphs 1101, 1102 and 1103.

With regard to claim 23, Applicant respectfully submits that one of ordinary skill in the art is enabled by the present application to make and use means for computing a simulation relation for the edge from the strengthened antecedent label, and comparing

the second simulation relation for the edge with a consequence label for a corresponding edge in a second assertion graph to check if the second simulation relation is contained by the consequence label without undue experimentation.

Applicant disclosed in the present specification (e.g. page 17 line 13 through page 18 line 21, [emphasis added]) that:

> For one embodiment, Figure 3a illustrates a method for computing the simulation relation for a model and an assertion graph. Box 311 represents initially assigning an empty set to the simulation relation for all edges e in the assertion graph that do not begin at initial vertex vI, and initially assigning Ant(e) to the simulation relation for all edges e that do begin at initial vertex vI. Box 312 represents marking all edges in the assertion graph active. Box 313 represents testing the assertion graph to identify any active edges. If no active edges are identified, then the method is complete. Otherwise, an active edge, e, is selected and marked not active as represented by box 314. Box 315 represents recomputing the simulation relation for edge, e, by adding to the simulation relation for edge e, any states which are in both the antecedent set for edge e and the post-image set for the simulation relation of any incoming edge, e', to e. Box 316 represents testing the simulation relation for edge e to determine if it was changed by the recomputation. If it has changed, all outgoing edges from e are marked as active, as represented by Box 317. In any case, the method flow returns to the test for active edges represented by Box 313.
>
> For example, Figure 4 shows changes over time in the assertion graph 201 resulting from simulation of the model 101. Initially only edge 413 and edge 414 have state s2 and state s1, respectively, associated with them. In the first subsequent iteration, state s3 is added to edge 426 since s3 is in the post-image of {s1} in model 101 and in the antecedent set of edge 426 in assertion graph 201. Similarly s4 is added to edge 425. In the next iteration, s6 is added to edge 436 because it is in the post-image of {s4} and in the antecedent set of edge 436. State s5 is added to edge 435 because it is in the post-image of {s3} and in the antecedent set of edge 435. In the final iteration, no new states are added to any edge. Therefore a fixpoint solution is reached.
>
> Comparing the final simulation relation for each edge, with the consequence set for that edge, indicates whether the model 101 strongly satisfies the assertion graph 201. Since {s1} of edge 444 is a subset of the consequence set S, edge 214 is satisfied. Since {s2} of edge 443 is a subset of the consequence set S, edge 213 is satisfied. Since {s4, s5} of edge 445 is a subset of the consequence set {s4, s5}, edge 215 is satisfied. Finally, since {s3, s6} of edge 446 is a subset of the consequence set {s3, s6}, edge 216 is satisfied. Therefore the final simulation relation indicates that model 101 strongly satisfies assertion graph 201.

Applicant further disclosed in the present specification (e.g. page 31 line 8 through page 32 line 24, [emphasis added]) that:

For one embodiment, Figure 12a illustrates a method for computing the simulation relation for a model and an assertion graph on the symbolic lattice domain ($\{B^m \rightarrow P\}, \subseteq_S$). Box 1211 represents initially assigning

$$Z = (\text{initE}(\underline{v}, \underline{v}') \wedge U) \cap_S \text{Ant}_S(\underline{v}, \underline{v}')$$

to the simulation relation for all edges ($\underline{v}$, $\underline{v}'$) in the assertion graph that do not begin at initial vertex vI, and initially assigning

$$\text{Ant}_S(\underline{v}, \underline{v}') = (\text{initE}(\underline{v}, \underline{v}') \wedge U) \cap_S \text{Ant}_S(\underline{v}, \underline{v}')$$

to the simulation relation for all edges ($\underline{v}$, $\underline{v}'$) that do begin at initial vertex vI. Box 1215 represents recomputing the simulation relation for edge ($\underline{v}$, $\underline{v}'$) by adding to the simulation relation for edges ($\underline{v}$, $\underline{v}'$), any states which are in both the antecedent set for edges ($\underline{v}$, $\underline{v}'$) and the post-image set for the simulation relation of any incoming edges ($\underline{v}^-$, $\underline{v}$) to ($\underline{v}$, $\underline{v}'$) produced by substituting any $\underline{b}$ in B^m for $\underline{v}^-$. Box 1216 represents testing the simulation relation labeling for edges ($\underline{v}$, $\underline{v}'$) to determine if it was changed by the recomputation. If it has changed, the method flow returns to the recomputation of simulation relation for edges ($\underline{v}$, $\underline{v}'$), represented by Box 1215. Otherwise a fixpoint has been reached and the method terminates at box 1216.

Using the method disclosed above for computing the simulation relation for a model and an assertion graph on the symbolic lattice domain ($\{B^m \rightarrow P\}, \subseteq_S$), the simulation relation $\text{Sim}_S(\underline{v}, \underline{v}')$ can be computed. In the first iteration the simulation relation becomes

$$\text{Sim}_{S1}(\underline{v}, \underline{v}') = (\neg u1 \wedge \neg u2 \wedge \neg u1' \wedge u2') \wedge (\neg x \wedge S1 \vee x \wedge S2).$$

In the second iteration the simulation relation becomes

$$\text{Sim}_{S2}(\underline{v}, \underline{v}') = (\neg u1 \wedge \neg u2 \wedge \neg u1' \wedge u2') \wedge (\neg x \wedge S1 \vee x \wedge S2) \vee (\neg u1 \wedge u2 \wedge u1' \wedge u2') \wedge (\neg x \wedge S3 \vee x \wedge S4).$$

In the third iteration the simulation relation becomes

$$\text{Sim}_{S3}(\underline{v}, \underline{v}') = (\neg u1 \wedge \neg u2 \wedge \neg u1' \wedge u2') \wedge (\neg x \wedge S1 \vee x \wedge S2) \vee (\neg u1 \wedge u2 \wedge u1' \wedge u2') \wedge (\neg x \wedge S3 \vee x \wedge S4) \vee (u1 \wedge u2 \wedge u1' \wedge u2') \wedge S5.$$

Finally in the fourth iteration the simulation relation becomes

$$\text{Sim}_{S4}(\underline{v}, \underline{v}') = \text{Sim}_{S3}(\underline{v}, \underline{v}')$$

resulting in termination of the method. Figure 11b shows the simulation relation 1004 for assertion graph 1103 on the unary symbolic extension of model 1001. For edge 1147, the fixpoint simulation relation is $\text{Sim}_S(vI, v1) = \neg x \wedge S1 \vee x \wedge S2$. For edge 1148, the fixpoint simulation relation is $\text{Sim}_S(v1, v2) = \neg x \wedge S3 \vee x \wedge S4$, and for edge 1149, the fixpoint simulation relation is $\text{Sim}_S(v2, v2) = S5$.

Comparing the simulation relation for each edge, with the consequence for that edge indicates whether the symbolic extension of model 1001 strongly satisfies assertion graph 1103. It will be appreciated that a containment comparison may be interpreted and also performed in a variety of ways, for example: by inspection to see if each element in a set Sj is also in a set Sk, or by testing if Sj intersected with Sk equals Sj, or by a computing a logical operation on Boolean expressions Sj and Sk such as $\neg Sj \vee Sk$.

With regard to claim 24, Applicant respectfully submits that one of ordinary skill in the art is enabled by the present application to make and use means for determining whether the simulation relation for the edge is contained by the consequence label for the edge without undue experimentation—for example by inspection to see if each element in a set Sj is also in a set Sk, or by testing if Sj intersected with Sk equals Sj, or by a computing a logical operation on Boolean expressions Sj and Sk such as $\neg$Sj $\vee$ Sk (p. 32, lines 20-24).

Accordingly, Applicant respectfully submits that one of ordinary skill in the art is enabled by the present application to make and use the entire scope of the invention as set forth in claims 21-24, as amended.

With regard to the undue breadth rejection of claims 20 and 22, the limitations of the canceled claim 20 have been included in claim 21 as amended and claim 22 is made dependant from claim 21.

Therefore, Applicant respectfully submits that claims 21-24, as amended, are presently in condition for allowance.

35 USC § 112, Second Paragraph Rejection

The Office Action indicates claims 1-15, 20-24 and 29-38 stand rejected under 35 USC § 112, second paragraph, as allegedly being indefinite for failing to point out and distinctly claim subject matter which applicant regards as the invention and being incomplete for omitting essential steps or elements citing MPEP § 2172.01.

Applicant respectfully notes that MPEP § 2172.01 states that a claim which omits matter allegedly disclosed as being essential to the invention may be rejected under 35 USC § 112, first paragraph as not enabling rather than the second paragraph.

As shown above, Applicant respectfully submits that one of ordinary skill in the art is enabled to strengthen an antecedent label for an edge in an assertion graph without undue experimentation.

Further, Applicant intends that the essential matter of strengthening an antecedent label is claimed and that the antecedent label is properly interrelated with the assertion

graph as being an antecedent label for an edge in the assertion graph. Applicant respectfully disagrees with the Examiner's reasoning with regard to "normal satisfiability," and the present (and canceled) claims since normal satisfiability is not a limitation set forth in the present (or canceled) claims. Therefore, Applicant respectfully requests the Examiner to withdraw the rejections of claims 3-9, 11-15, 21-24 and 30-38, as amended, under 35 USC § 112, second paragraph.

35 USC § 101 Rejection

The Office Action indicates claims 10-15 and 35-38 stand rejected under 35 USC § 101 for allegedly reciting a process comprising an abstract idea.

Claim 11, as amended, includes the limitations of canceled claim 10 and sets forth strengthening a first antecedent label for an edge in an assertion graph, wherein strengthening the antecedent label comprises: joining pre-images of antecedent labels of any outgoing edges from the edge in the assertion graph; and keeping, in the strengthened antecedent label for the edge, states already contained by the first antecedent label for the edge and also contained by the joined pre-images of antecedent labels of any outgoing edges from the edge.

The Office Action states that claim 11 does not produce a practical application having a useful, concrete and tangible result. Applicant respectfully disagrees.

Applicant disclosed in the present specification (e.g. page 31 line 8 through page 32 line 24, [emphasis added]) that:

> Methods for formal verification of circuits and other finite-state systems are disclosed herein. For one embodiment, formal definitions and semantics are disclosed for a model of a finite-state system, an assertion graph to express forward implication properties and backward justification properties for verification, and satisfiability criteria for automated verification of forward implication properties and backward justification properties. For one embodiment, a method is disclosed to perform antecedent strengthening on antecedent labels of an assertion graph.

The method set forth in claim 11 transforms a useful data structure, an assertion graph, and enables a category of properties for the practical application of formal

verification of finite state machines. Although claim 11 sets forth limitations of the data structure using mathematically correct terms, the application of formal verification is arguably interesting only because of its applicability to verifying finite state machines for example as embodied in electronics and software products.

Similarly Claim 35 sets forth expressing a justification property with an assertion having at least one antecedent to represent pre-existing states and stimuli for a finite state machine, and also having at least one consequence to represent possible resulting states for the finite state machine; strengthening said at least one antecedent of the assertion, and verifying said justification property using the at least one strengthened antecedent and said at least one consequence.

The Office Action states that claim 35 does not produce a practical application having a useful, concrete and tangible result. Applicant again respectfully disagrees.

As hardware and software systems become more complex there is a growing need for automated formal verification methods. These methods are mathematically based techniques and languages that help detect and prevent design errors thereby avoiding significant losses in design effort and financial investment.

Formal verification of finite state machines represents one of the most substantial investments in computing resources used in the microprocessor industry. An error or flaw in an arithmetic circuit, for example, can result in multiple millions of dollars in losses of revenue, manufacturing time, inventory and competitive advantage.

Therefore, Applicant respectfully requests the Examiner withdraw the rejections under 35 USC § 101 of claims 11-15 and 35-38, as amended.

35 USC § 102 Rejection

The Office Action indicates claims 1-2, 10, 20 and 29 stand rejected under 35 USC § 102(a) as allegedly being anticipated by Sipma et al, "Deductive Model Checking," Formal Methods in System Design, v. 15, pp. 49-74, (1999) (hereafter Sipma).

Applicant does not agree that claims 1-2, 10, 20 and 29 are anticipated by Sipma, but has canceled claims 1-2, 10, 20 and 29 in the present application to pursue them further in a continuation application. Therefore, Applicant reserves the right to refute the alleged anticipation by Sipma of claims 1-2, 10, 20 and 29 in the future.

CONCLUSION

Applicant respectfully submits the present claims for allowance. If the Examiner believes a telephone conference would expedite or assist in the allowance of the present application, the Examiner is invited to call Lawrence M. Mennemeier at (408) 765-2194.

Authorization is hereby given to charge our Deposit Account No. 02-2666 for any charges that may be due.

Respectfully submitted,
BLAKELY, SOKOLOFF, TAYLOR & ZAFMAN

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